more thoroughly carbonised, the central core became blocked with pitch and tar distilled forward into the coal mass, and the gas and tar vapour being in this latter stage forced to find their way through the outer shell of red-hot coke, became degraded to the utmost limit, and gave very large volumes of such permanent gases as hydrogen mingled with methane, the least easily broken up of the hydrocarbons, the result being that the modern tar is in reality a mixture of low temperature and very high temperature tar. Such a tar, obtained from a good gas coal, will contain approximately:—

Benzol	0·60 per cent.
Toluene	0·15 ,,
Solvent naphtha	1·00 ,,
Heavy naphtha	1·65 ,,
Carbolic acid	0·6 ,,
Cresylic acid	0·9 ,,
Creosote oil	30·6 ,,

The remainder is naphthalene, anthracene, and pitch.

If the gas from the carbonisation be scrubbed, and the absorbed hydrocarbons be distilled out from the creosote oil and added to the light hydrocarbons obtained from the tar, the total yield is:—

Benzol	2·1 per cent.
Toluene	2·1 ,,
Solvent naphtha	2·6 ,,
Heavy naphtha	2·6 ,,

It is found in practice that the carbonisation under the ordinary gasworks conditions of a ton of good bituminous coal yields about one-third of a gallon of toluene from tar and gas.

In practice, the withdrawal from the gas of all the hydrocarbons that can be scrubbed out by creosote oil would reduce the heating value of the gas to a considerable extent, and various methods of getting over this trouble have been proposed, such as enriching the scrubbed gas by the benzene and xylene from the crude benzol after separation of the toluene by fractional distillation, or by so scrubbing the original gas that only about one-third of the crude benzol is withdrawn, as by such means the calorific value of the gas can be maintained at or above the statutory minimum of 500 British thermal units.

The tar and gas made in small country works as a rule contain more aromatic hydrocarbons than the products from large works, as the temperatures used in carbonisation are not so high; and should the Government need still larger quantities of toluene and carbolic acid for nitration, the gasworks of the Empire could treble the output by reverting to the temperature and methods employed before the introduction of regeneration in the furnaces. This, however, would reduce the gas yield from the 13,000 cubic feet per ton now aimed at by the gas manager to 10,000 cubic feet, but the higher calorific value of the gas would allow of the volume being made up by the addition of blue water gas.

THE ELECTRONIC THEORIES OF THE PROPERTIES OF METALS.

In a course of lectures delivered at the Cavendish Laboratory during the Michaelmas term of 1886, Sir J. J. Thomson examined the dynamical result of assuming the passage of electricity through a metal to be of the same nature as through an electrolyte. The subject was dealt with more completely in "Applications of Dynamics to Physics and Chemistry" in 1888. The later discovery of the electron which might act as a carrier of electricity from molecule to molecule placed the idea on a much firmer footing, and in 1898 Riecke developed theories of the electrical and thermal conduction and thermo-electrical properties of metals, based on the existence between the molecules of carriers of positive and negative electricity. Two years later Drude worked out more systematically theories founded on the same basis, and it is his work which is usually quoted in accounts of electronic theories, generally with the simplification that only one type of carrier—the negative electron—is taken as moving freely between the molecules. These electrons are supposed to be produced by the dissociation of the electrically neutral metal atoms, what remains of the atom being left positively charged.

The moving electrons are assumed to have the same average kinetic energy as a molecule of a gas enclosed in a cavity in the metal would have. The nature of the impact of electron on metal atoms is not discussed, but as the motion of each metal atom is likely to be comparatively small, the gas laws which hold for the motions of the molecules of a light gas amongst those of a much heavier are applied and the electrons are said to have a mean free path of length λ. The motions are distributed in all directions equally, and the electrons cannot escape through the surface of the metal unless their speed perpendicular to the surface exceeds a certain limit. The action of ultraviolet light on the surface facilitates the emission.

When an electromotive force is applied to the metal there is superposed on this to and fro motion of the electrons a drift up the electric field, the relation of which to the field is such that the specific conductivity of the metal is proportional to $n\lambda/\sqrt{T}$ where n is the number of free electrons per cubic centimetre and T is the absolute temperature of the metal. Since the electrical conductivity of a pure metal is known to vary approximately inversely as the absolute temperature, this implies that $n\lambda$ must vary inversely as $\sqrt{T}$. As there is nothing on the one hand to suggest so considerable a change of the free space between the metal atoms with temperature, while on the other the facts of thermoelectricity are against any considerable decrease in the number of electrons per c.c. as the temperature rises, it sems difficult to reconcile the law of variation of $n\lambda$ with experimental facts.

If a slope of temperature exists in a metal, the electrons coming from the hotter side of a cavity between two metal atoms will move more rapidly than when coming from the colder. There will therefore be a drift of energy towards the colder metal which bears to the slope of temperature such a relation that the heat conductivity of the metal is proportional to $n\lambda\sqrt{T}$. As the heat conductivity of a pure metal changes very little with change of temperature, this equation again implies that $n\lambda$ varies inversely as $\sqrt{T}$, and we have the same difficulty in understanding how this is brought about. On dividing the heat conductivity by T times the electrical conductivity the product $n\lambda$ disappears from the result, and we obtain a constant the value of which should be approximately $2{\cdot}3 \times 10^8$ for all metals at all temperatures. At air temperatures the values found experimentally vary between 2 and 3×10^8, and at very low temperatures between $1{\cdot}5$ and 3×10^8. The agreement between the two results is undoubtedly good, but when the calculations are improved in accuracy by taking into account the variation of the speeds of the electrons about the mean value used by Drude, Lorentz finds the constant $1{\cdot}5 \times 10^8$, which is not in such close agreement with experiment. For alloys and conducting salts the experimental values are considerably higher than for pure metals, and Koenigsberger and others have put this down to the part played by the atoms themselves in the conduction of heat. For quartz and other electrical insulators which are good conductors of heat there can be no question of the insignificance of the *rôle* of the free electrons.

Owing to the different values of the concentration n of electrons in different metals, there will be a flow of electrons through the surface of contact of two metals till the potential difference produced stops the flow. In an unequally heated metal the same process of compensation will occur. In the former case we get the Peltier and in the latter the Kelvin effect. The former agrees in order of magnitude with the values found by experiment, but as Sir J. J. Thomson has pointed out, it is difficult to reconcile the great decrease of electrical conductivity of a metal on melting with the small Peltier effect between solid and molten metal. The calculated Kelvin effect shows that the concentration n of the electrons must in all metals be nearly proportional to $\sqrt{T}$, a result which is not easily reconciled with that for $n\lambda$ deduced from the electrical or thermal conductivity.

Since a negative electron in motion in a magnetic field is acted on by a force transverse to its path, the theory affords a simple explanation of the Hall effect, and gives the right sign and order of magnitude for the effect in bismuth at ordinary temperatures, but the wrong sign for the effect at low temperatures, and for the effects at ordinary temperatures in iron and antimony.

In no field can the simple electron theory be said to have given a satisfactory quantitative account of the facts, and its elaboration in one region has in general led to greater difficulties in others. The kinetic energy of the electrons it postulates is so great that an increase of 1° C. in their mean temperature involves a supply of heat ten times the specific heat of the metal. After pointing this out Sir J. J. Thomson, in 1907, in his "Corpuscular Theory of Matter," developed a new theory which may be called the doublet theory. According to this theory the atoms of a metal are grouped together in pairs, one of each pair positively, the other negatively charged. In ordinary circumstances the axes of these doublets point in all directions on the average equally. Under the action of an electric field the doublets tend to arrange themselves in lines, with the positive end of one near the negative of the next, and electrons may pass from the negative end of one doublet to the positive of the next, and so along the line of doublets.

On the assumption that the axis of the doublets distribute themselves according to the gas law, that their centres are spaced on the average b apart while the charges of the same doublet are d apart, and p electrons are discharged from a doublet per second, the electrical conductivity of the medium works out proportional to $nbdp/T$ where n is the number of doublets per c.c. and T the absolute temperature. The experimental facts show that $nbdp$ is independent of temperature. In the same way the transport of kinetic energy by an electron leaving a doublet at a higher, and joining one at a lower temperature, leads to a heat conductivity proportional to nb^2p, which the experimental facts show is independent of temperature. The quotient of the heat conductivity by T times the electrical conductivity on this theory comes $2{\cdot}6b/d \times 10^8$, and as b/d must be greater than unity the agreement with the experimental value 2 to 3×10^8, is about as good as in the case of the simple theory. The presence of the b/d makes it possible to include in the theory those substances for which the quotient is high.

At the junction of two metals the excess flow from one metal will cause a difference of potential and an electric field which will change the orientation of the doublets until the flows are equalised. In an unequally heated metal the same method of compensation will come into play, and we have the Peltier and Kelvin effects.

If the rotation of a doublet in an electric field does not take place about the middle point, the two charges of the doublet move with different speeds. If they are in a magnetic field its action on them will tend to incline the axis of the doublet to the plane containing the two fields, and there will be a flow of electrons at right angles to both fields. The direction of the flow will be determined by that of the end of the doublet which moves most quickly. We thus have an explanation of the Hall effect, whether it be positive or negative.

No numerical comparisons of theory with experiment appear to have been made in the case of these thermo-electric and thermo-magnetic effects.

In his addresses to the Institute of Metals on May 5, and to the Physical Society on June 25, Sir J. J. Thomson dealt with the modification of his theory necessary to bring it into line with the discovery by Prof. Kamerlingh Onnes that at very low temperatures—4° or 5° absolute—the electrical conductivities of metals become infinite. The external electric field applied to the metal is assisted in bringing the axes of the doublets into line by the field produced by those doublets already in line. The kinetic energy of thermal motion of the doublets tends to destroy the alignment. At ordinary temperatures it is sufficient to destroy the alignment so soon as the external field is withdrawn, and the flow of electrons from doublet to doublet is stopped. But at very low temperatures the energy is not sufficient to modify an alignment once produced, and the flow of electrons continues when the external field is withdrawn. The conductivity in these circumstances will be very high.

From this short account of the present position of the two theories it will be seen that the doublet theory of Sir J. J. Thomson has shown a greater power than the electron theory of co-ordinating the facts of experiment. It has difficulties of its own, both in the nature of its fundamental assumptions and in its power of reproducing the facts quantitatively. It does not appear to provide electrons for emission by incandescent bodies, and in its latest development it involves serious changes not previously suspected in the thermal, thermomagnetic, and thermogalvanic properties of metals at the very low temperatures attained by Prof. Kamerlingh Onnes. But the great flexibility it has shown justifies a more generous treatment of it by those authors and lecturers who have been content to limit their exposition of these questions to the older electron theory.

C. H. LEES.

THE STERILISATION OF WATER.

THE safeguarding of our water supplies is of particular importance at the present time, for there may be considerable risk of pollution if typhoid and cholera cases or "carriers" arrive in any number from the seats of war, as may well be the case. The research work carried out by Dr. Houston is therefore of much value and is summarised in a Report just issued.[1]

Dr. Houston first deals with his "excess lime" method of purification. The hardness of water is chiefly due to bicarbonate of lime (temporary) and sulphate of lime (permanent), the former being kept in solution by the carbonic acid present. In the softening of water lime is added and combines with the free and semi-combined carbonic acid, causing a precipitation of the lime added and of the bicarbonate of lime in the water in the form of the relatively insoluble carbonate of lime. A water treated with the right amount of lime has no caustic alkalinity and has practically no action on the bacteria present. When more than enough lime is added the water is rendered caustically alkaline and becomes actively bactericidal. Such a water would, however, be unfit for domestic and trade use, but if the excess of lime present be removed by the addition of a sufficiency of water from which the bacteria have been removed, the whole of the mixed water will be softened and purified, and will be satisfactory for all purposes. Dr. Houston has previously shown that if raw river water be stored for from four to five weeks the great majority of the bacteria are removed, and the water is rendered safe for drinking purposes.

The excess lime method of purification consists, then, in the addition of an excess of lime, storage of the alkaline water for a day or thereabouts, so that the bactericidal action may be exerted, addition of a sufficiency of water, purified by storage, to neutralise the excessive alkalinity, and filtration to remove the precipitated carbonate of lime.

Dr. Houston has tested the method on a large scale at Sunbury and at Aberdeen. At Aberdeen *Bacillus coli* (which may be taken as an index of pollution) was present in the untreated water in from 1 c.c. to 100 c.c.; after treatment it was not found in 100 c.c.; the process is therefore efficient and it is comparatively inexpensive.

Another research which has been carried out by Dr. Houston is an investigation of "water microbes" giving the cholera-red reaction after incubation of cultures for twenty-four hours. The cholera-red reaction (obtained by adding acid to a culture) is a very constant and characteristic reaction of the cholera microbe, and as this organism is frequently conveyed by water, it is important to know whether water organisms other than cholera yield the reaction. It is satisfactory to find that, although eighty microbes out of approximately 1885 sub-cultures gave the cholera-red reaction on first being tested, they were easily distinguished from cholera by the application of two or three further simple tests.

Dr. Houston is to be congratulated on the valuable research work he has been able to carry out in the midst of a vast amount of routine work.

R. T. HEWLETT.

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[1] Metropolitan Water Board. Eleventh Report on Research Work, together with Index to Research Reports, Nos. i–x inclusive. By Dr. A. C. Houston. Pp. vii+52. (London: Metropolitan Water Board, n.d.) Price 2*s*. 6*d*.

THE LATE PROF. J. COOK WILSON.

DEATH has of late been busy among Oxford residents. The demise of John Cook Wilson, Wykeham Professor of Logic, was not unexpected, for he had been in bad health for more than a year, and indeed had never recovered completely from the shock of his wife's death in January, 1914. Cook Wilson was a man of quite exceptional attainments. Born at Nottingham and educated at Derby School, he matriculated at Oxford in 1868. As scholar of Balliol he took no fewer than four first classes, two being for mathematics and two for classics. These were followed by the Latin Essay, the Conington Prize, and a fellowship at Oriel. After his election as Wykeham Professor he became a fellow of New College, but his affection for Oriel never waned, and his connection with his old college was of late